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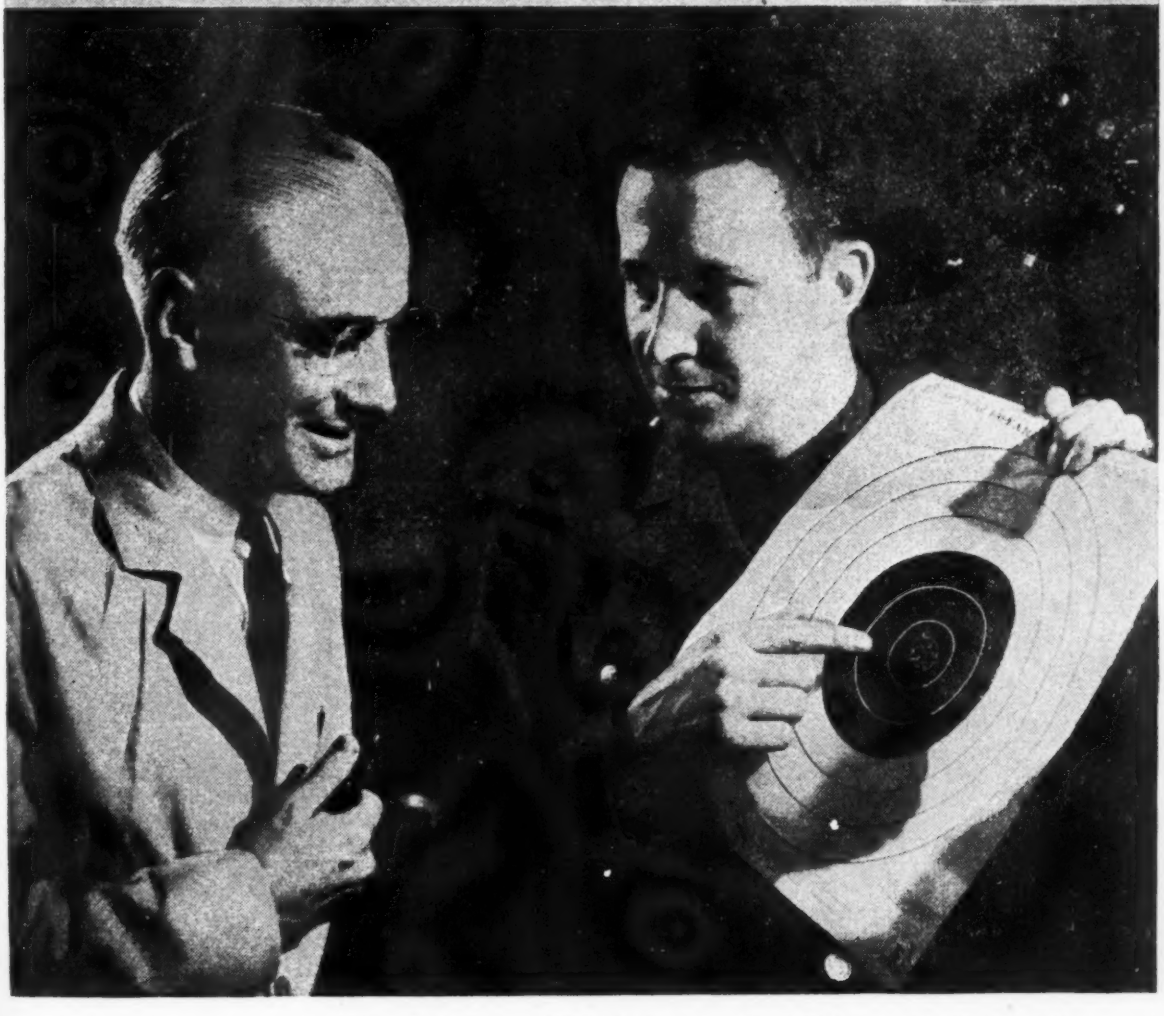

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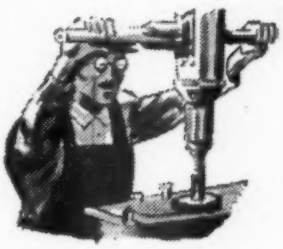

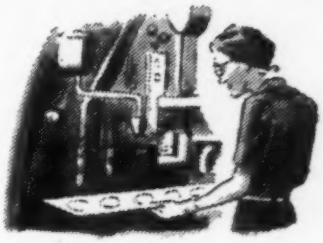

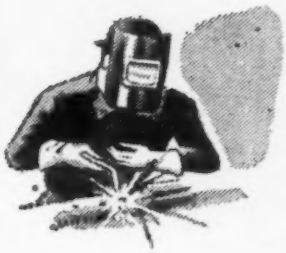

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A COMPARISON OF DUANE'S AND DONDERS' TABLES OF THE AMPLITUDE OF ACCOMMODATION.*

H. W. Hofstetter
School of Optometry, Ohio State University

It is generally recognized by optometrists that the measurement of the amplitude of accommodation is of value in prescribing lens additions for near work. In the interpretation of the amplitude finding it is of importance to know what is considered normal for the age of the patient being examined.

The values that are commonly considered as normal are usually based either on the averages obtained by Donders (1, 2) or on those obtained by Duane (3, 4, 5). For practical clinical purposes it presents no serious problem to employ either table of values since normal variations from individual to individual include both sets of data. The trends of the data as presented by the two authors give rise, however, to the questions, first, which of the two tables more accurately describes the change of accommodation with age, and secondly, how the difference can best be explained.

Although Duane's curves are based on a many times larger number of cases it is not easy to disregard the data of an investigator as renowned as Donders. This reluctance is shown by the fact that current authors do not show a predominant preference for either, while many text books include the tables of both.

The present paper is therefore concerned with an analysis of the original data as presented by Duane and Donders to demonstrate the nature and possible causes of the apparent differences.

Donders had for his purpose the determination of the nature of

*An abridgment of the material presented before the Ohio Section of the American Physical Society, May 6, 1944, at Columbus, Ohio. Submitted on June 26, 1944, for publication in the September, 1944, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

the onset of presbyopia in that it had been suspected that the recession of the near point of accommodation began in late adult life. Donders' data, Fig. 1, therefore represent the actual recession of the near point for people who were emmetropic or nearly emmetropic during early adult life. The testing procedure consisted, briefly, in a selection of the maximum plus lenses (or minimum minus) which permitted maximum acuity at distance through which was determined the nearest point of clear vision. A set of thin vertical wires was used as a test object to detect the presence of a blur. In the cases in which this procedure was followed the reciprocal of the distance of the near point of accommodation from the nodal point of the eye was a direct measure of the amplitude. The nodal point was considered to lie approximately 7 mm. behind the cornea.

Donders, however, recognized that in addition to a progressive decrease in amplitude there occurred in late adult life an increase in hyper-

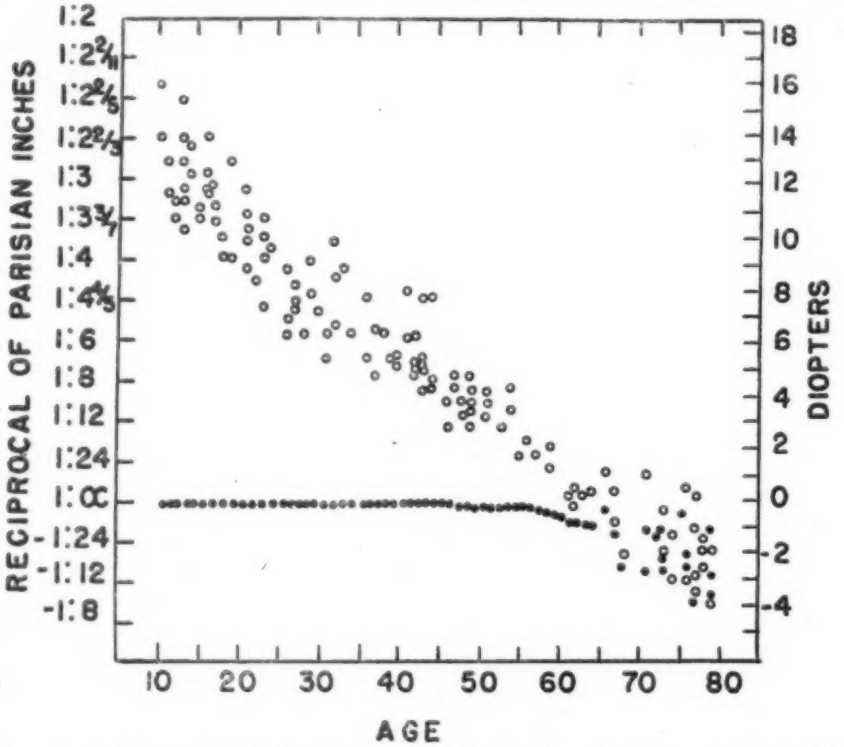

Figure 1. The trend of the far points (dots) and near points (circles) according to Donders. The specifications are made with respect to the anterior nodal point of the eye.

opia which in itself would account for much of the recession of the near point. Since he wished to demonstrate the actual course of the emmetropic near point with age as well as the decrease in ability to accommodate, he plotted the values of both the far point and the near point on the same graph. In this way the amplitude is represented by the difference between the near point and far point values.

In Fig. 1 from Donders (2) each circle represents the near point of accommodation for one individual while each dot represents a far point. Each division of the ordinate on the left side of the graph represents a change in accommodation corresponding to the reciprocal of 24 parisian inches. Since one meter equals approximately 37 parisian inches these divisions correspond to steps of 1.54 diopters each. The equivalent in diopters is shown on the right hand side of the figure.

The far point values are seen to follow the zero value up to the

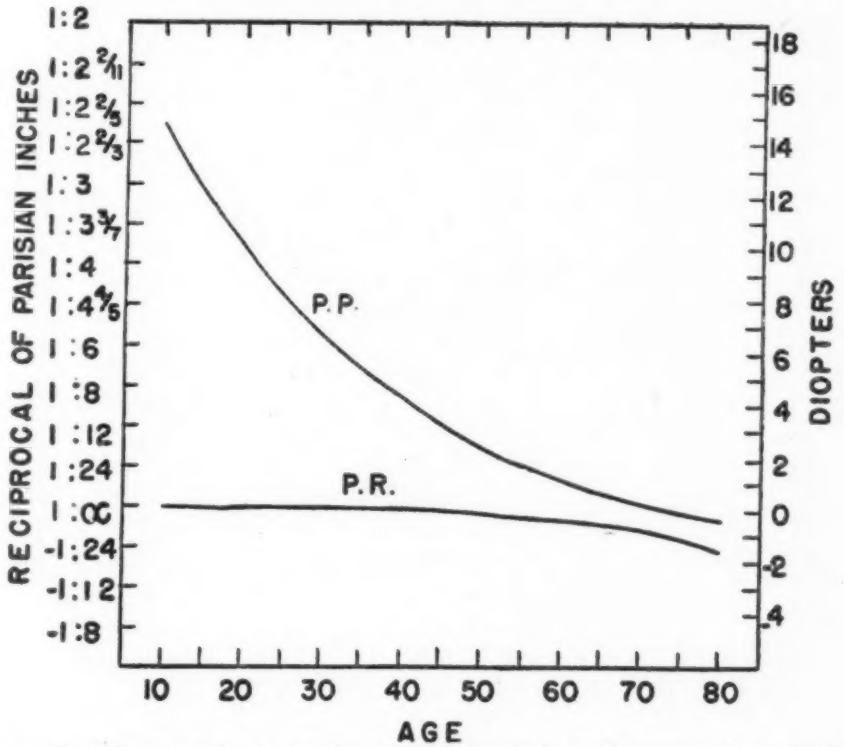

Figure 2. The trend of the far point (P. R.) and near point (P. P.) according to Donders. The specifications are made with respect to the anterior nodal point of the eye.

age of about 46. This does not mean that all of the subjects under 47 represented in this graph were exact emmetropes, but rather that the data from those with small degrees of ametropia were represented as the equivalent of emmetropes by simple calculations allowing for their refractive errors. The near point values for these cases therefore give the amplitudes directly.

The far point values for those over 46 deviate from the zero line to show the trend of the refractive error in late adult life. The cases so plotted are for individuals who had previously been emmetropic. In other words, the far points were plotted without first correcting for the existing refractive error. As the graph is presented it is not known which far point values correspond to given near point values although in an earlier graph (1, p. 218) of a smaller number of cases Donders had indicated how these were paired. Consequently, to demonstrate the trend of the amplitude above the age of 46 it is necessary to construct curves to represent the averages of these values and to compute the average amplitude at each age from the vertical separation of these curves.

Donders has drawn such curves in the graph represented in Fig. 2. A comparison of Figures 1 and 2 shows that the curves do not follow the trend of the data very closely. For example, the near point data obtained near the age of 40 are seen to be considerably higher than the near point curve. Evidently Donders did not consider his data sufficient to warrant constructing anything but a simple and regular curve from one extreme to the other. It is to be kept in mind, however, that Donders' subsequent table of expected amplitudes is based on these curves rather than on the actual data.

One additional point to be made in connection with Donders' results is that each of the near point values represented the "absolute" near point which he defined as that amount of accommodation attainable with the maximum amount of convergence. To emphasize this point Donders defined three types of accommodation measurements, the "relative," the "binocular," and the "absolute." The "relative" near point of accommodation was that obtained with the lines of sight remaining parallel. The "binocular" was that obtained with the lines of sight converging for the test object. This corresponds to what is commonly referred to as the near point obtained by a simple binocular push up test. The "absolute" was that obtained when the eyes were made to converge to a maximum. All three determinations represent, therefore, binocular tests only in the sense that both eyes were used.

For practical purposes he considered the amount of convergence in play sufficient to permit the "absolute" accommodation whenever the test object could be made to advance within 8 parisian inches (approximately 22 cm.) of the eyes. When the test object could not be advanced this much without blurring he placed convex lenses before the eyes to bring the near point of clear vision within this distance in order to provide a sufficient amount of convergence to permit the maximum accommodation. The only additional modification of this procedure to insure a sufficient amount of convergence was that of occluding one eye whenever the convergence associated with accommodation was excessive. He resorted to this modification in a few cases only because of the mechanical limitations of his apparatus in providing an excessive stimulus to convergence. The excessive convergence of the occluded eye during the test in these instances would be taken as evidence that the subject was putting forth an extreme effort to accommodate.

It is obvious that Donders' procedure can not be adequately described by simply stating that it is binocular, for this does not bring one's attention to the precautions that Donders took to insure an ample amount of convergence during the test. On the other hand the procedure can not be adequately described by stating that it is monocular, for, although a monocular test would theoretically eliminate convergence as a limiting factor, Donders recognized the value of binocular vision as an indirect influence on the amount of accommodation effort that the subject would exert.

Since a distance of 8 parisian inches from the eyes corresponds to an angle of convergence of about 16° for an average pair of eyes, we can briefly summarize the one aspect of Donders' procedure by stating that the near point of accommodation in each case represented that obtained when the eyes were converging at least 16°. Such a statement allows for the instances in which greater convergence was employed to obtain the maximum accommodation values.

Several writers have replotted Donders' curves, rather than the actual data, from his scale of parisian inches to diopters without changing the point of reference, the nodal point, which Donders assumed to be approximately 7 mm. behind the vertex of the cornea. The dioptric differences between the near point curve and the far point curve at various ages have subsequently been given, with slight variations, in tabular form as a table of expecteds or normals (6, 7).

Since most ocular refraction measurements are currently made with

reference to the spectacle plane the use of these expecteds for comparison with clinical findings involves an error dependent upon the distance between the position of the assumed spectacle plane and the assumed nodal plane as reference points. Since Duane variously assumed the spectacle plane to lie 13 and 14 mm. in front of the cornea the difference in position of the points of reference would be 20 or 21 mm.

Duane has at various times reported the results of his measurements of amplitudes, each successive report representing an additional number of measurements. In his first report (5) he compared his findings with Donders' by computing the equivalent of Donders' curve in terms of a point 13 mm. in front of the cornea. The values so obtained compared unfavorably with the limited number of findings Duane had made in that the computed curve was higher at ages less than about 20 and at ages more than about 45 while the curve was lower for the intermediate ages. Because of this deviation he continued making tests until he had accumulated data on more than 4000 eyes in order to establish a more valid set of expected values than could be assumed from Donders' curves. His subsequent data essentially verified his original findings.

Duane's testing procedure differed from Donders' in several respects:

1. Duane determined the refractive error under homatropin in all cases under 47 years of age. The correction so obtained was then considered as the correction which made the eye artificially emmetropic so that the near point obtained through this correction gave the amplitude directly as the reciprocal of the distance from the near point to the spectacle plane 13 or 14 mm. in front of the cornea. Most of the measurements were made from a plane 14 mm. in front of the cornea.

2. The statistical data which Duane compared to Donders' were obtained monocularly. Duane, however, was aware of the frequent failure of the monocular stimulus to elicit the full amplitude of accommodation. Therefore, to minimize the possibility of a failure on the part of a subject to exert his maximum accommodation effort, Duane resorted to repeated testing and carefully worded instructions to the subject. Each recorded amplitude represented the highest value obtained for the eye being tested.

3. The distance of the near point was measured with a 50 cm. rule. Hence, in those instances in which the near point was beyond 50 cm. it was necessary to use auxiliary lenses to make the test within the range of the rule. The proper allowance was of course made for the auxiliary lens in computing the amplitude.

4. Although Duane was in many cases able to demonstrate a higher

amplitude binocularly than monocularly he chose to use the monocular values in constructing his amplitude curves. This is to be mentioned as specifically different from Donders' procedure in that Donders had regularly taken advantage of this type of information as evidence that the absolute amplitude was not always reached unless the maximum convergence was in play. Duane, too, was aware of the fact that his higher binocular values may have been due to an additional accommodation effort not in effect in the monocular test since he had demonstrated to his own satisfaction that there was no significant decrease in pupil size and no summation of acuity in the binocular tests.

A point to be considered in this same connection is the possibility that Duane did not make an allowance for the fact that his binocular measurements were made along the median sagittal plane of the head. The measuring rule was placed in the median sagittal plane for both the monocular and binocular tests, but the test object was moved along the side of the rule in the monocular test and along the top of the rule in the binocular test. Hence, the distance from either eye to the test object would be greater for a given scale reading when it was placed in the median plane than it would be for the same scale reading when it was placed directly anterior to the eye. This would, in effect, give an apparently higher value binocularly for a given amount of accommodation. This possible difference is quite negligible, however, in comparison to the actual differences reported by Duane. For example, it can be computed that for 10 diopters of accommodation the apparent difference would amount to an increment of less than half a diopter for the binocular. The actual increases that Duane found for the subjects who manifested about 10 diopters ranged from a half to four diopters. Since we can not be certain that Duane failed to make this allowance in comparing the binocular and monocular findings, and since Donders likewise did not make any special reference to this point, no corrections have been assumed for this in the analysis to follow. In fact, the conclusions to be derived from this analysis would not have to be modified if a correction were assumed.

5. Duane used a narrow vertical line drawn on a card as a test object. The doubling or blurring of the line was used as an indication that the near point had been reached. Since Donders used thin vertical wires as a test object it is probably satisfactory to assume that the difference in test objects would not provide appreciably different results.

The results of Duane's monocular tests are shown in Fig. 3. Be-

cause of the wide range covered by the galaxy of dots in this graph, Duane preferred to consider any amplitude normal which fell reasonably within the limits of this range. To represent this galaxy more schematically he then constructed three curves, one to represent the average, and the other two to represent normal limits. These curves are shown in Fig. 4. The limiting curves are intended to include the major part of the galaxy as one might judge from a general inspection. It is doubtful that they represent any particular degree of distribution that might be expressed by a simple statistical term. Approximately it may be stated

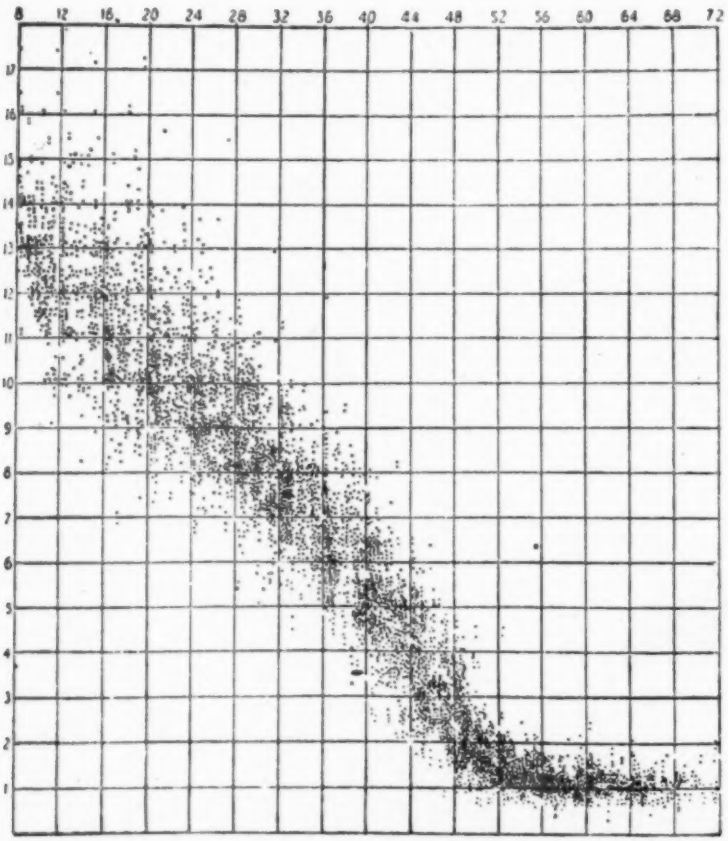

Figure 3. Values of monocular accommodation according to Duane. Each dot represents the maximum value in diopters of the accommodation in a given eye. The results obtained in over 4,200 eyes are here plotted. The specifications are made with respect to the spectacle plane assumed to be 14 mm. anterior to the cornea.

that each limiting curve appears to follow a course between the first and second standard deviation.

In comparing his own data and curves to those of Donders, Duane concluded that Donders' values in general were lower, particularly those obtained from middle-aged people. He went a step further in attributing the low amplitudes to Donders' failure to use a cycloplegic in determining the distance refractive error. The following quotation from Duane (3, page 865) illustrates his view, "For example, Donders assumed that a middle-aged individual who had normal vision and did not accept a convex lens was emmetropic. This assumption, we know, is far from correct—such subjects often having a latent hyperopia of

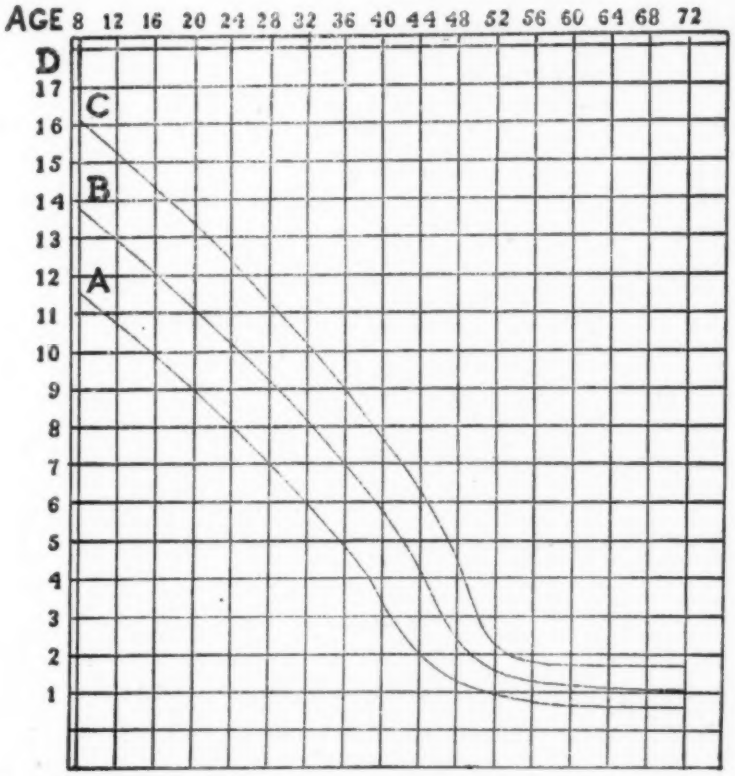

Figure 4. Accommodation curve according to Duane. A represents the extreme minimum and C the maximum limits of those dots in the whole mass shown in Figure 3, which Duane considered to represent normal values. B is the curve representing the mean value of the accommodation.

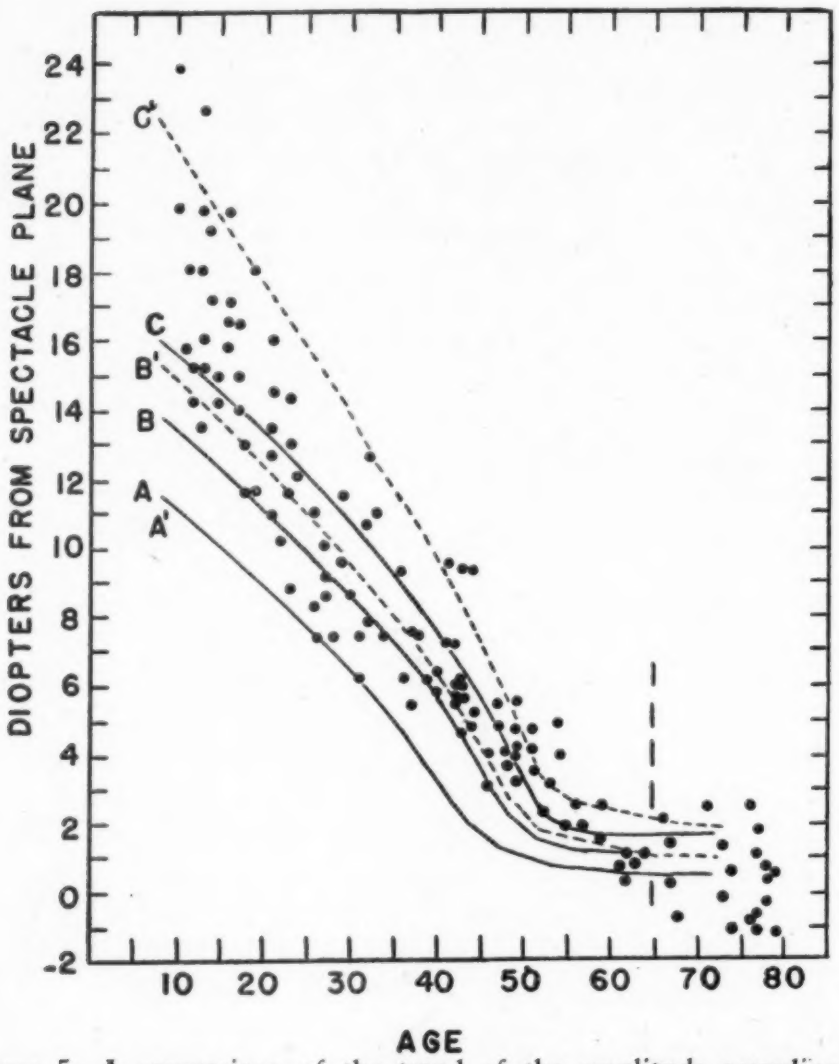

Figure 5. A comparison of the trend of the amplitude according to Donders (dots) and according to Duane (curves). All specifications are made with respect to an assumed spectacle plane 14 mm. anterior to the cornea. A, B, and C represent Duane's minimum, mean, and maximum monocular values respectively. A′, B′, and C′ represent Duane's minimum, mean, and maximum binocular values respectively. The scattering of Donders' findings above the age of 65 is exaggerated by the computation method employed in transcribing the original data.

a diopter or more. The failure to recognize this hyperopia would obviously make the estimate of the accommodation in the subject tested just that much too low."

The following analysis not only fails to support this conclusion but actually reverses the problem so that, contrarily, it becomes necessary to explain why Duane's values are not as high as Donders'. Thus, in Fig. 5 it is seen that Donders' amplitude values, the dots, expressed in relation to the spectacle plane instead of the nodal plane are, in general, higher than the range shown by Duane's curves, A, B, and C.

In addition to making the correction for the spectacle plane as a point of reference it is necessary to determine the dioptric differences between Donders' far points and near points to compute the amplitude. To do this it is simplest to compute each point with reference to the spectacle plane in accordance with the following formula:

$$D = \frac{1}{\frac{1}{\frac{1}{1.54\ N}} - 0.021}$$

D = the dioptric value of the distance from the far or near point to the spectacle plane fourteen millimeters in front of the cornea. N = the ordinate value of the far or near point as plotted in Donders' original graph using each space as a unit of accommodation. Donders' units each represented the reciprocal of 24 parisian inches measured from the nodal point. Thus, if Donders found the near point to be at 12 parisian inches, the reciprocal would equal one twelfth, or two twenty-fourths, making N = 2.

The coefficient 1.54 represents the ratio between Donders' unit and the diopter as a unit. The coefficient 0.021 represents the distance between the nodal point 7 mm. behind the cornea and the spectacle plane 14 mm. in front of the cornea.

Since it cannot be ascertained from Donders' graph which far point value corresponds to each near point value, the correct amplitude cannot be computed for the individual subjects in the age range for which the individual far points deviate from a mean trend, namely, for ages above 65.

For this reason the computations are based on the mean trend of

the far point. The estimated mean trend is shown by the curve in Fig. 6 which gives the far point values corrected for the spectacle plane. The curve is seen to follow the actual data up to the age of 65 and to approximate the mean beyond this. Since the values indicated by the curve are used in the computation of the amplitude the values obtained for ages

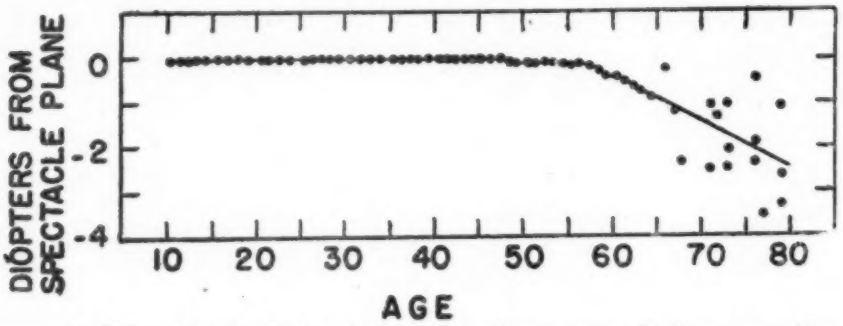

Figure 6. The trend of the far point of accommodation according to Donders. The dioptric values of the far points are specified with respect to the assumed spectacle plane 14 mm. anterior to the cornea. The straight line is intended to represent the mean of the scattered data.

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above 65 (cf. Fig. 5) do not represent individually true values. That is to say that only the trend of the mean above this age is of significance and that the apparent increase in deviation from the mean is therefore to be disregarded.

For the purposes of this analysis it would have been satisfactory to omit the data for ages above 65, and to this end there is included in Fig. 5 a vertical dashed line at the age of 65 to indicate the limit of the age range within which the plotted points represent the individually correct findings.

The resultant values plotted in Fig. 5 easily show, first, that Donders' findings do not fall within the range of Duane's proposed normal limits, curves A and C, and, secondly, that the mean of Donders' results lies strikingly higher than Duane's mean curve B at the earlier ages, while it lies practically coincident with Duane's mean at the advanced ages.

Fortunately for this analysis the explanation is to be found in part at least in the results Duane (3) obtained in comparing the binocularly and monocularly measured amplitudes of several hundred subjects.

Duane's summary of his observations on the excess of the binocularly measured amplitude over the monocularly measured amplitude usually found at different ages is represented in Table I.

Comparison of Monocular and Binocular Accommodation at Different Ages

Age	Excess of binocular over monocular accommodation
	Usual excess in D.
8-15	0-6
39-44	0-3.4
16-34	0-2.5
	Extreme excess in D.
45-50	1-2
35-38	0.5-1.5
51 and higher	0-1.5

Table I.

From Duane (3, page 868).

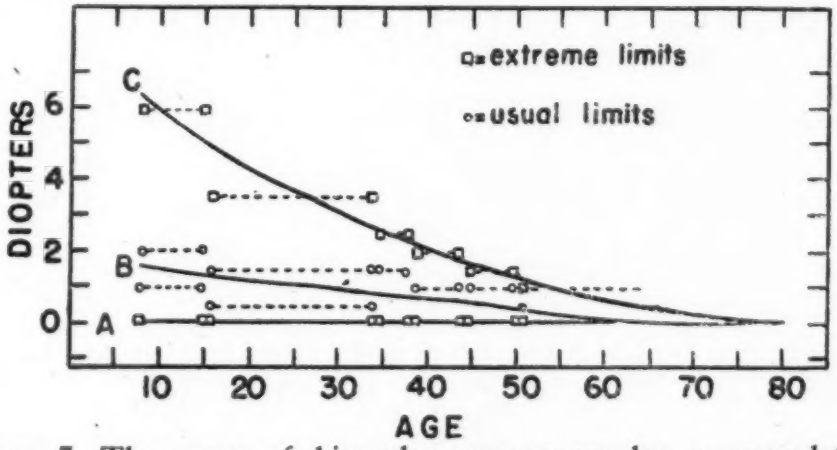

Figure 7. The excess of binocular over monocular accommodation according to Duane.

These tabulated values are plotted as dotted line segments in Fig. 7. The limits of the range of extreme excesses are approximated by curves A and C. The mean of the range of the usual excesses is approximately by curve B. If the values represented by curves A, B and C in Fig. 7 are combined with the respective values of curves A, B and C in Fig. 5,

the resultant curves, A′, B′ and C′ in Fig. 5 can be considered to represent the minimum, mean, and maximum values of the binocularly measured amplitudes respectively.

The direct comparison which now can be made in Fig. 5 shows that Donders' data can hardly be considered to differ significantly from Duane's binocular results. In view of the small number of findings offered by Donders no other conclusion is possible. It is of interest, however, to consider that the differences that do exist may be real and to try to explain them on some other basis than a normal variation. Of special interest are the high values Donders obtained for ages less than twenty years and for the ages between 40 and 60 years.

Below the age of 20 the ability to accommodate is so great that the near point of accommodation is rarely further from the spectacle plane than three inches. Small errors in linear measurements within this range result in large errors expressed in diopters. For example, the dioptric deviation that would be produced by an error of one-fourth of an inch in the linear measurements would be greater than the difference between Donders' and Duane's mean values for the ages under twenty. The effect that such an error would have on the dioptric values for older subjects would be relatively negligible.

Between the ages of 40 and 60 the near point of accommodation usually lies between 15 and 80 cm. from the spectacle plane. Related to this is the fact that Donders used auxiliary lenses to place the nearpoint within a distance of about 20 cm. from the spectacle plane whenever it would otherwise lie beyond this distance, while Duane used auxiliary lenses only when the nearpoint would otherwise lie beyond a distance of 50 cm. This means, then, that for most of the subjects between the ages of 40 and 60 Donders made use of stronger auxiliary lenses than Duane did, and in many instances he used auxiliary lenses when Duane would have used none at all. It is possible, therefore, that the greater values obtained by Donders in this age range are to be attributed to the greater amount of convergence in play during the tests or to the greater effort of accommodation invoked by the realization of the nearness of the test object. It would follow from this that Duane's findings in this age range may not represent the maximum amplitude and that therefore the rapid fall in amplitude shown in his curves to culminate near the center of this range remains open to question.

In regard to the regions of the graph in which the two investigators show almost perfect agreement, namely, between the ages of 20 and 40

and beyond 60, it may be said for the former group that the amplitude testing procedures were essentially alike, while for the latter group the accommodation had reached the zero level of response and the factor or factors which might influence the amount of accommodation effort put forth in any test would not differentiate the results.

In view of the foregoing analysis it is evident that neither the trend of the accommodation represented by Duane's curves nor that represented by Donders can be considered conclusive. Donders' curve is supported by an insufficient number of data; Duane's curve on the other hand may have acquired its distinguishing features from the possibility of a failure to elicit the maximum amplitudes between the ages of 40 and 60. Stated in another way, the two sets of data are in agreement at the ages between 20 and 40 and above 60 but Donders' data describe a curve with an upward concavity while Duane's data describe a curve which for the most part has a downward concavity.

It becomes apparent that the information at hand does not justify the use of any specific curve to represent the trend of the amplitude with age. For clinical purposes, however, it is of some value to know even approximately the changes in accommodation to be expected with increases in age and so the use of a straight line to represent the changes would be convenient. A simple straight line relationship between age and amplitude can, of course, be considered nothing more than a compromise of Donders' and Duane's findings.

On the assumption of this simple relationship it can then be said that, approximately, the measured amplitude of accommodation decreases at the rate of 0.3 diopters per year until it reaches a value of 0.50 at the age of 60. After the age of 60 there is little if any change to be expected. The fact that the measured amplitude levels off at a value greater than zero is not to be taken to mean that there always exists some available amplitude, but that more likely there exists a deficiency in the method of measurement.

Related to this analysis are the little mentioned data obtained by Kaufman* (8) in an investigation of the amplitude of accommodation of about 400 eyes.

Kaufman's procedure was not described in detail so that it is difficult to compare his results directly with either Duane's or Donders', although Kaufman intended his investigation to duplicate Donders' on a larger

*My appreciation is expressed to Donald P. Bixler of Decatur, Indiana, for the use of a copy of his translation of Kaufman's dissertation.

number of subjects. Kaufman did not specify either the nodal point or the spectacle plane as a point of reference; he described his measurements as being made "from the eye." Also he used a reading card (Schweigger's) for most cases, and in the remaining cases, presumably illiterates, he used a point test (Burkhart's). He used only cases with normal or near normal

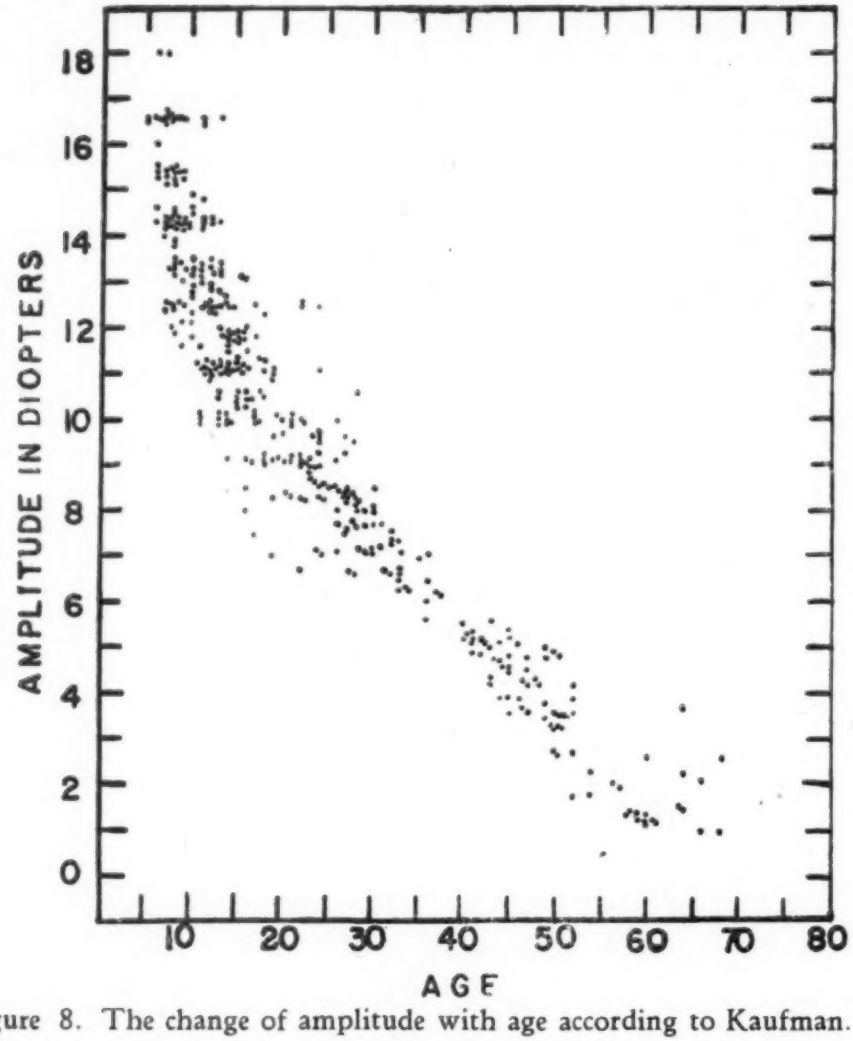

Figure 8. The change of amplitude with age according to Kaufman.

acuity and none with high refractive errors or showing pathological symptoms. He considered the distance subjective examination finding to represent the zero level of accommodation and employed only those subjects whose subjectively indicated correction agreed with the skiascope

finding. He followed Donders' procedure in using convex lenses whenever the near point of accommodation was beyond 22 cm. From the fact that he specified the amplitude for each eye separately it is to be taken that his tests were monocular.

Kaufman's results are shown plotted in Figure 8. Since the data are not corrected to represent measurements from the spectacle plane they are not directly comparable to the data in Figure 5. However, there are certain features in the graph which can be considered for the purposes of this analysis.

First of all, it is seen that the data correlate very closely with Donders', Figure 1. Secondly, the leveling off of the amplitude is seen to occur at about the age of 60. And finally, there exists no rapid drop in amplitude between the ages of 40 and 60 as obtained by Duane. Any correction of these data that may be made for an assumed spectacle plane would still permit these observations. These, then, further support the suggestion that Duane failed to elicit the maximum amplitude in the range between the ages of 40 and 60.

It was pointed out above that Duane's lower amplitude findings in this age range may have been due either to an insufficient amount of convergence in play during the tests or to the reduced effort of accommodation afforded by the awareness of the great distance of the test object. Kaufman's results would indicate that binocular vision is not necessary to produce an adequate amount of convergence. In the absence of binocular fixation, however, the convergence cannot be said to be stimulated directly and therefore can only be considered to be a by-product of accommodation. In this sense, convergence is not to be thought of as a direct means of eliciting maximum accommodation in an amplitude test, but rather only as a possible limiting factor when not permitted to function free of the fusion stimulus provided by the test object. Donders was emphasizing this same aspect of convergence when he differentiated between "relative," "binocular," and "absolute" accommodation. Hence, it is doubtful that Duane's lower findings were due to an insufficient amount of convergence during the test since his monocular findings were just as low, or lower, than his binocular findings.

There would remain, then, only the second possibility mentioned above, namely, that the awareness of the distance of the test object on the part of the subject has an important influence on the amount of accommodation effort exerted and that it could be this factor which pro-

duced the lack of agreement between Donders' and Duane's data in the 40 to 60 age range.

SUMMARY

The correction of Donders' amplitude findings for the spectacle plane shows them to be generally higher than Duane's monocular findings. This observation contradicts Duane's conclusion that Donders' findings were lower. It likewise contradicts Duane's conclusions that Donders failed to obtain the true far point of accommodation by not using a cycloplegic.

The correction of Duane's "normal" values to represent his binocular results affords much better agreement between his and Donders' results. The failure to obtain complete agreement is due to the greater amplitudes obtained by Donders in the age ranges below 20 years and between the ages of 40 and 60.

The higher values obtained by Donders in the range of ages less than 20 years cannot be considered significant because of the reduced accuracy of measurement involved at this age level.

The higher values obtained by Donders in the age range between 40 and 60 may be due to a difference in procedure which becomes more pronounced for low amplitudes. An analysis of this difference in procedure gives rise to the suggestion that the nearer testing distance employed by Donders provided a more adequate stimulus to accommodation. Hence, it is doubtful that Duane elicited the maximum accommodation in the age range between 40 and 60.

This analysis of the information at hand does not justify the use of any specific curve to represent the trend of the amplitude with age.

Approximately, it can be assumed for clinical purposes that the measured amplitude decreases at the rate of 0.3 diopters per year until it reaches a value of 0.50 diopter at the age of 60, after which no decrease is to be found.

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THE "CONCEPT OF COLOR" FROM THE COLORIMETRY REPORT OF THE OPTICAL SOCIETY OF AMERICA*

D. L. MacAdam and Loyd A. Jones
• and the Colorimetry Committee, Optical Society of America

Colors differ among themselves in three independent respects. Consequently, a three-fold description is necessary and sufficient for the classification of colors. The three characteristics of color were first recognized subjectively, and consequently the ideas applicable to the description of color sensations are most familiar and furnish the most suggestive example of the triple system of classification. A color sensation is described when the hue, saturation, and brightness of the sensation are stated. The hue can be described in terms of the familiar adjectives, red, green, blue, yellow, purple, and so forth. The description of saturation is not commonly undertaken beyond the use of rather vague terms, such as vivid, strong, and weak. The terms brilliant, pastel, pale, and deep, which are sometimes used as descriptive of saturation have connotations descriptive also of brightness. The description of a color sensation as bright or dim constitutes a statement of the brightness of the sensation. Brightness is the attribute** of color sensation which is most distinctly quantitative. This is a consequence of the fact that it is the attribute which varies most markedly when the magnitude of the stimulus is changed. The terms high brightness, medium brightness, and low brightness are appropriate for the description of the brightness of color sensation. Saturation also has a quantitative, as well as a qualitative character, and the use of the terms high saturation, medium saturation, and low saturation are suitable for the description of the saturation of color sensations. When, in a stimulus consisting of a combination of chromatic and achromatic light, the proportion of the chromatic component is in-

*For a number of years the Colorimetry Committee of the Optical Society of America has been working on a report designed to bring order into the definitions and concepts of color, and to provide useful data. The Society expects to publish the entire report in book form when completed. This portion of the material which is greatly abridged, will appear in Chapter II of this book. It is suggested that the reader refer to "The Historical Background and Evolution of the Colorimetry Report of the Optical Society of America" by Loyd A. Jones, published in the August 1944 issue of this journal. This present section of the report is an abridgment of the material which appeared in the Journal of the Optical Society of America. Vol. 33, No. 10, pp. 544-554. 1943.

**The noun "characteristic" may be read in place of "attribute" if such substitution will clarify the discussion for those who are not familiar with the psychological usage

creased, the saturation of the color sensation varies correspondingly. In the sense that it varies in the same manner as the proportion of the chromatic component in the stimulus, saturation may be considered a quantitative attribute of color sensation. Hue is rarely considered to be a quantitative attribute of color sensation.

COLOR: CHARACTERISTICS OF LIGHT

Likewise, there are three characteristics of light in terms of which color may be specified. These are dominant wave-length, purity, and luminance. These characteristics of color correspond in a general way to the hue, saturation, and brightness attributes of color sensation. The attributes of color sensation and, also, the characteristics of color depend upon the phenomena of human vision, upon the kind of radiant energy and upon the rate at which it impinges on the retina. The radiant energy, which is the stimulus, may be specified by giving its spectral composition expressed in absolute units. The correlations between the spectral composition of the stimulus and the attributes of the resulting sensation are exceedingly complex. These correlations are greatly simplified when the intermediate psychophysical concepts are employed.

COLOR SENSATION: AN ELEMENT OF EXPERIENCE

Experience is so complex that the sensation of color is never experienced entirely apart from other elements of experience. These other elements of experience supplement and often modify, to some extent, the interpretations which we place on our sensations of color. Recognition and classification of objects according to the colors of the light they reflect is a most familiar process. In such recognition and classification, variations of many characteristics of objects, such as size, shape, gloss, texture, etc., are either ignored or discounted. Every experience is a unique event, the exact duplicate of which has never occurred in the past and can never recur in the future. Every analysis and classification of experiences involves the process of abstraction. Every classification necessarily discounts the uniqueness of each experience. Every abstraction stresses one feature of experience and subordinates or ignores all other features. In particular, visual perception is a variety of experience which can be analyzed into elements, the similarity or difference of which permits the classification and description of visual perceptions. The recognition of such elements is necessary for any classification and study of actual experiences. The reality of these elements is frequently denied, because each is an abstraction never experienced apart from other ele-

ments. Such arguments usually conclude by attributing reality only to the whole unanalyzed experience. The intuitive recognition of elements of experience is, nevertheless, useful for orderly thinking, and doubt of their reality never interferes with their use.

MODES OF APPEARANCE

The following classification of modes of visual appearance is based on elements of visual perception. The attributes of the various modes of appearance are commonly considered to be descriptive of the *stimulus object.*

Shape and size are attributes possessed by all modes of visual appearance

Transparency, varying from complete opacity to complete transparency, is an attribute possessed by all located modes of appearance.

In *located modes* of appearance the stimulus object appears to be within definite limits of distance from the observer.

Non-located modes of appearance lack the attribute of location.

The *aperture mode* of visual appearance is exhibited within the field aperture photometers and colorimeters, and is the most common example of a non-located mode.

The *illumination mode* of appearance, which results from the awareness of the distribution of illumination in space, is classed as a located, but not as an object mode of visual appearance.

The *illuminant mode* of appearance of sources of light is a located mode.

The *object mode* of visual appearance is a located mode, which is further subdivided into:

Volume mode which has the attribute of *transparency* (excluding complete opacity), and

Surface mode which has the distinctive attribute of *glossiness,* as well as the attributes of less than perfect transparency.

These modes of visual appearance and their distinctive attributes can be recognized and classified independently of any classification of color. On the other hand, the recognition of color accompanies and supplements the recognition of modes of appearance. For instance, a glossy surface can be recognized as such if variations of color (primarily differences of luminance between highlights and surrounding areas) can be recognized in the light incident on the observer's retina from various portions of the observed object.

The distinction between color and the attributes by which modes of appearance are recognized and classified is emphasized in order to make clear the procedure which will be followed in this report, in which color is discussed apart from any discussion of the modes of appearance which are perceived whenever the presence of color is perceived. Certain words, however, are associated with particular modes of appearance. For instance, the words "black" and "white" are commonly descriptive of *opaque* objects, although such usage is by no means exclusive. The use of these words for the description of aperture colors, of self-luminous sources, and of transparent materials, requires rather careful re-definitions which will not be attempted in this discussion.

Terms implying a dependence of color on some of the other attributes of visual appearance should be avoided. Thus, it is sometimes said that the color of one liquid is a transparent blue as distinguished from another whose color is said to be a murky blue. The same meaning can be conveyed just as clearly, without implying that transparent and murky are descriptive of the color, by stating that the first liquid is transparent and blue and that the second liquid is murky and blue. The usage recommended indicates that the descriptive terms for mode of appearance and color are mutually independent. The liquids may have a common color, describable as blue, although they differ in another characteristic, describable as transparent or murky, which is readily distinguished from the color characteristic.

Gloss is a characteristic which is readily distinguished from color, even though the comparison of the colors of surfaces which differ in gloss is frequently puzzling and difficult. Although they differ in appearance, air, water, and non-selectively absorbing mirror surfaces are not commonly considered to be different in color. It is rather uncommon to associate color with such materials. The colors seen in or through such "colorless" materials are commonly associated with the objects seen by reflection or transmission.

The use of the names of materials for color names is frequently confusing because characteristics of the materials, other than color, are frequently suggested by such names. Gold, silver, and copper, are occasionally used as color names, but since the peculiar mode of appearance of metals is associated with these names, their use constitutes more than a color name, by suggesting also a familiar metallic luster. Like transparency, metallic luster is a characteristic of objects distinguishable from

color, and names suggesting such characteristics should not be used as color names.

PSYCHOLOGICAL CONCEPTS

Sensation is the mode of mental functioning which is directly associated with stimulation of the organism.* It is specifically the direct result in consciousness of the present stimulation of the sense organs, as distinguished from *perception* which includes the combination of different sensations and the utilization of past experience in recognizing the objects and facts from which the present stimulation arises.

PSYCHOPHYSICAL CONCEPTS

Specifications of *stimuli* in terms of *equality*, or *differences*, of *sensations* experienced by human observers are called psychophysical measurements The methods employed for the establishment of such measurement techniques, as well as the techniques themselves, are called psychophysical methods, and the concepts defined by the operations employed in these measurements are called psychophysical concepts. Although psychophysics is not limited to such methods and concepts, the discussion of psycholphysics in this report will be limited to measurements based on equality and differences of sensations.

Since complex interactions between the responses of sense organs contribute to almost every sensation, there can be no assurance that a one-to-one correlation will exist between any sensation and the most nearly corresponding characteristic of the stimulus. Psychophysical methods of measuring such characteristics of stimuli give results that are related in a reasonable manner to the sensations experienced by representative observers under representative conditions of observation. In all

*Further refinement of the definition of sensation tends to reduce its content, until, finally the concept is robbed of most of its customary meaning. As a result of such refinement of the concept, one school of modern psychology has arrived at the conclusion that it is useless to attempt to isolate pure sensation from the perceptual aspect of experience. For the purpose of clarity of exposition and appeal to the understanding of the readers for whom this report is intended, the unsophisticated concept of sensation described at the beginning of this section has been adopted. This concept does not imply any theory of the relation between sense organs and sensations, nor does it exclude the possibilities that simultaneous or successive responses of the same or different sense organs may interact without the observer being conscious of the interaction. Such interactions, which may be responsible for the phenomena of color constancy, adaptation, after-images, and contrast effects, would modify the sensations so that no invariant one-to-one correspondence could exist between stimulus and sensation. Adoption of common usage retains sensation as a meaningful concept. Several perceptions can have their origin in the same group of stimuli. The unpredictable and unclassifiable results of conscious judgment, which render each perception unique, are ignored in the process of analysis.

branches of science, physics, chemistry, and physiology, as well as in psychophysics, standardization of the conditions of measurement is necessary for the establishment of any practically useful measurement technique and for the unambiguous definition of the quantities measured. Obviously, the quantities measured and the concepts defined by psychophysical measurements are not sensations.

PHYSICAL AND PHYSIOLOGICAL CONCEPTS

For the sake of orderliness and clear thinking on the subject, it seems desirable to divide the subject of color vision into a few definite categories. Let us consider, therefore, the sequence of events which lead to the elicitation of visual sensation. Perhaps a somewhat fanciful outline may be helpful in such a discussion. It may serve also to illustrate the subdivision of our subject matter into three sections.

A radiator, that is a "source of light" in common parlance emits radiant energy. *Radiant energy* is energy traveling through space in the form of electromagnetic waves of various lengths. As indicated, this radiant energy, after being emitted by the radiator, is propagated through intervening space and falls upon an object. Here some of the radiant energy is absorbed, some may be transmitted through the object, and some reflected. As indicated some of the reflected radiant energy is propagated through space and enters the eye, being refracted by various elements of the eye in such a way that an image of the object is formed on the retina.

The amount of radiant energy incident on the object is, of course, determined by the amount of radiant energy emitted by the source, by the distance between the source and the object, and by various aspects of the space through which it travels from the source to the object. The material occupying this space may be such that some of the radiant energy is absorbed or deflected so that it does not reach the object.

The reflected radiant energy in traveling from the object to the eye where it enters the cornea of the eye, may also be modified both in intensity and in quality by the occurrence of absorption (including losses by scattering and reflection) by any materials in the intervening space.

PSYCHOPHYSICS

The third major subdivision into which the study of color will be classified, psychophysics, exists because there are important applications

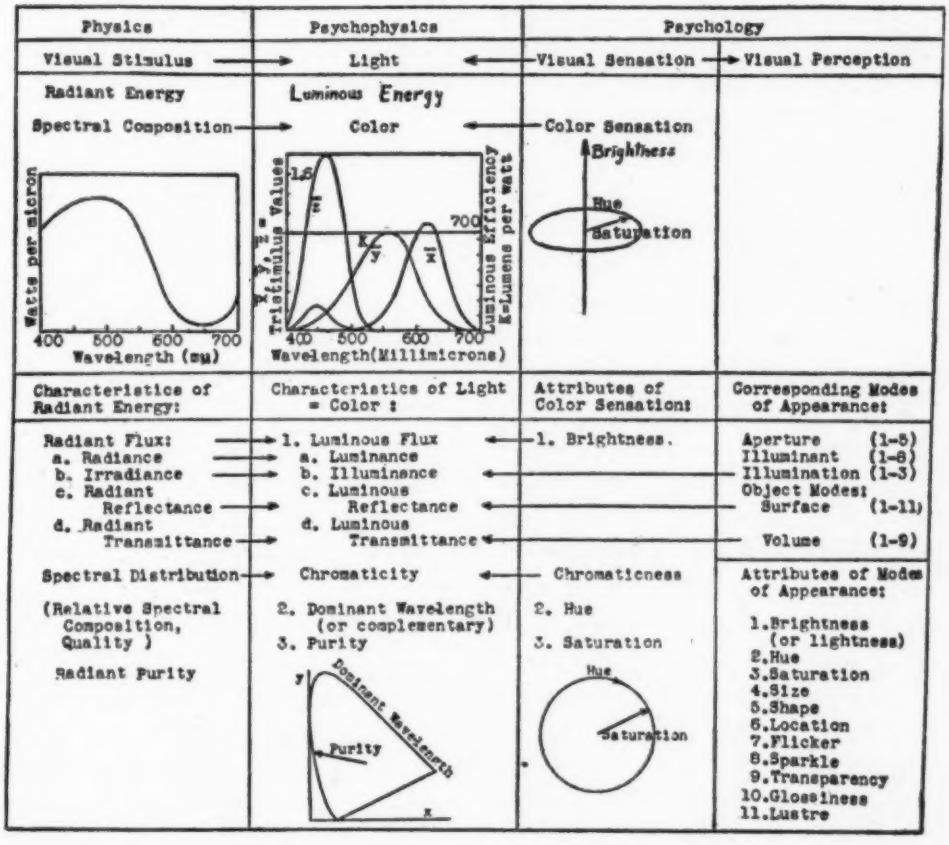
of relationships which can be discovered between physical stimuli and the sensory or perceptual aspects of the responses to these stimuli. For all practical purposes, psychophysical relationships are definitions, in physical terms, of concepts derived from the subjective aspects of the response of the human organism to physical stimuli. The criterion of subjective significance governs the relationships on which the definitions are based. Since this use of the introspective criterion introduces all of the variabilities and peculiarities of individual observers into psychophysical relationships, these relationships are, strictly speaking, variable, dependent on the observer and not universally verifiable. The usefulness of concepts and relationships based on average values of the psychophysical relationships for many observers has led to the inclusion of these averaged and standardized relationships in the category of psychophysics. Some authors, who ignore the human significance of these data in order to create an illusory simplicity for the purposes of engineering, look upon the concepts defined by these standardized relationships as purely physical because the fact of standardization has been substituted for the criterion of subjective reasonableness. Some authors regard luminance, for instance, as a derived physical quantity, since it can be computed from the spectro-radiometric data of the emitting surface by use of the standard phychophysical data without the necessity for any visual observation or measurement. Such a point of view is quite misleading and inadequate for the discussion of color. The concepts, such as luminance, which are defined by the standardized psychophysical relationships, are classed as psychophysical in this report. We know that the radiant energy coming to us from the sun is composite in character, consisting of a mixture of radiant energies of many different wave-lengths or frequencies. By using a suitable dispersing system, this radiant energy can be separated into its component parts. Now we can take a given amount of some particular frequency and find how much of another frequency is required to produce a "brightness" (sensation) equal to that produced by the first sample. By continuing this process until all frequencies which are capable of stimulating the eye have been compared with the first sample or standard, we may determine how efficient radiant energies of the various frequencies are for the production of "brightness." This efficiency we may term the *luminous efficiency*, meaning that it is a numerical expression of the quantity of light corresponding to a given sample of radiant energy. It is evident that this luminous efficiency is a quantity that is neither purely physical nor purely psychical, but is a

relationship between the psychical and physical aspects of radiant energy. We say, therefore, that *luminous efficiency* is a *psychophysical term* or *quantity*. As we shall see later, the particular relationship which expresses the dependence of luminous efficiency on the freqeuncy of radiant energy is a particularly important one in the solution of many color problems.

CLASSIFICATIONS OF CONCEPTS RELATED TO COLOR

We feel that the discussion given in the preceding paragraphs has established the reasonableness of our proposal to subdivide the subject matter with which we must deal in the study of color into the following sections:

1. Psychological concepts and relationships.
2. Physical concepts and relationships.
3. Psychophysical concepts and relationships.



Therefore, we may proceed to classify the more important concepts with which the discussion of color is concerned under the headings of the names of the science, physics, psychology, and psychophysics as is illustrated in the chart, some extent the concepts named at corresponding positions in the several columns are closely related, but in some cases, such as in the listing of the modes of appearance and the attributes of these modes, the parallelism of the columns has been abandoned in order to exhibit the dependence of the appropriate photomteric quantity on the mode of appearance. The concepts included under the category of psychology have been divided, for convenience, into sensory and perceptual classes. The division greatly aids in the clarification of the relations between the physical and psychological phenomena, which are the subject matter of the science of psychophysics. The co-ordinated contributions of the sciences of physics and psychology to the science of psychophysics are indicated by the arrows at the heads of the columns. The contributions of the sensory elements of experience to the more highly elaborated experiences classed as perceptions are also indicated by an arrow from the term visual sensation toward the consequence, visual perception.

The evaluation of radiant energy in terms of its capacity to produce brightness as already been discussed. This evaluation of the spectroradiometric curve (shown in the physical column) is accomplished by use of the luminous efficiency function which is represented by the curve labled *K* in the psychophysical column. The resultant quantity is called the quantity of light or luminous energy. Luminous flux is the rate of flow of luminous energy. The luminous flux incident on a definite area of the retina corresponds to the brightness attribute of visual sensation. The quantities, luminance, illuminance, luminous reflectance, and luminous transmittance are similarity evaluated in terms of luminous flux by use of the luminosity function, *K*. These several different alternative manners of exprssing the quantitative characteristics of light are used in the appropriate situations described opposite them in the column of the perceptual concepts. The parentheses following the names of the modes of appearance indicate the attributes which each mode may exhibit. The code used in these parentheses is given under the heading "Attributes of modes of visual perception." Only three of these attributes correspond closely to concepts included under the other categories. The other seven attributes are usually perceived by human observers because of the spatial and temporal characteristics of visual stimuli.

The characteristics of light which are specified by dominant wavelength and purity may also be specified by the location of a point in the chromaticity diagram shown at the bottom of the psychophysical column. Chromaticity includes both of these characteristics, and corresponds to the concept of relative spectral composition or quality of radiant energy, and to the chromaticness* of visual sensation. The circular diagram at the bottom of the psychological column indicates the type of classification which is suitable for the description of the chromaticness of color sensations. Since, when a complete series of hues is arranged in a subjectively reasonable sequence, the first member of the series always very closely resembles the last member, the hues are reasonably arranged in a closed curve, of which the circle is the simplest and most commonly adopted form. Similarly, when the saturations of all hues are decreased, the sensations all approach a common residual or neutral which may be represented by a point somewhere within the closed hue circuit. For simplity this neutral or achromatic sensation is represented by the center of the hue circle and various saturations of any one hue are represented by points along a radius of the circle. Increasing distance from the center signifies increasing saturation. The general classification of color sensations requires the addition of a third dimension for the representation of the brightness attribute, in the manner indicated at the top of the column labeled color sensation. The three distribution functions represented at the top of the psychophysical column are the basis for the internationally standardized method of evaluating color in terms of equivalent stimuli, consisting of the combination of three standard stimuli. The intensities of the three standard components in the stimulus equivalent to any color can be determined as the totals of the spectro-radiometric data of the sample weighted by each of the distribution functions shown. Color may be specified by the "tri-stimulus values," which result from the calculations just described. The proportions of two of the tri-stimulus values in the total of the three are represented by the coordinates of the point representing the color in the chromaticity diagram. The dominant

*Chromaticness is a new term, suggested here for the first time, which is purely tentative and designed to fill a gap in the naming of corresponding psychophysical and psychological terms. That the need is real is indicated by the prevalent indiscriminate use of the term chromaticity in both the psychological and psychophysical senses. Chromaticness is subject to change in favor of any name agreed upon by psychologists for exclusive use in the subjective sense, corresponding to the psychophysical concept of chromaticity. The ending "-ness," which conveys some idea of magnitude is no more objectionable in this term than in whiteness, glossiness, and even brightness, which require statements of "what kind" as well as "how much" for complete descriptions.

wave-length and purity of the color are simply and directly related to the location of the point in the chromaticity diagram. The hue and saturation attributes of color sensation and perception correspond to the psychophysical characteristics of color: dominant wave-length and purity. The scale of values shown on the right-hand side of the diagram representing the standard distribution functions indicates that the curve representing the luminous efficiency of radiant energy of various wave-lengths is identical in shape with one of the standard tristimulus distribution functions. The corresponding tristimulus value of any color is directly proportional to the photometric intensity of the light, and this value is used as the specification of color which corresponds most directly with the brightness attribute of color sensation.

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PROBLEMS IN GLAUCOMA*

In considering problems in the diagnosis and treatment of glaucoma certain questions must be asked. To answer these, the records of the Department of Ophthalmology of the University of Minnesota for the three years, 1940-42, inclusive, have been reviewed.

The questions to be discussed are:

*An abridgment of the material presented to the optometrists of Minnesota by the Minnesota Society for the Prevention of Blindness, 503 Hamm Building, St. Paul, Minn. Submitted for publication, as part of a "Control of Glaucoma" program, on February 15, 1944.

1. Is glaucoma a common disease? Is the incidence increasing or decreasing?

2. What therapeutic results are obtained?

3. What are the reasons for failures?

4. What can be done to prevent unfavorable results in the future?

I. *Is the incidence of glaucoma increasing?*

Considering the fact that one clinic alone treated 306 glaucoma patients in the course of three years, it seems obvious that glaucoma is a fairly common disease. For purposes of comparison one finds that at the University Hospital clinics slightly over twice this number of patients with diabetes mellitus were treated during the same period. In comparison to incidence with iritis, cataracts and all other diseases of the eye, the incidence of glaucoma was 9.3 per cent.

The incidence of glaucoma has increased 34 per cent since 1928, according to the University records. It is not known whether glaucoma actually is increasing in incidence, but undoubtedly the augmented number of cases is due at least in part to the increased awareness of physicians, optometrists and patients to the importance of ocular care and diagnosis. It is not impossible that the tension and strain of modern life is a causative factor in the real or apparent increased morbidity just as it may be a factor in vascular hypertension. The fact that the number of reported cases of glaucoma seems to be increasing year by year is significant, but difficult to explain.

II. *What therapeutic results are being obtained?*

Of 285 patients who have required surgical procedures for the control of glaucoma, the results in 87 or 30.8 per cent were recorded as good, and in 63 or 22 per cent as fair. In the treatment of ocular hypertonicity the results are classified as good if the patient maintains the visual acuity and the visual fields which he has at the beginning of treatment. Very slow progression of the glaucomatous process must at present be classified as a fair or satisfactory result. Glaucoma in this regard is like tuberculosis: Arrest is the prime objective. Summarizing, 150 or 52.8 per cent of the patients receiving surgical treatment for glaucoma obtained good or satisfactory results.

However, enucleations or eviscerations of the eyeball numbered 96 or 33.7 per cent of all surgical cases. In all except six cases, the condition was untreated or almost or wholly untreated and resulted in absolute and incurable glaucoma with blindness. This emphasizes the fact that a large percentage of patients come at a time when enucleation or eviscera-

tion is the only remedy. This large proportion of obviously hopeless eyes may bespeak the carelessness and indifference of patients, but the factors of transportation difficulties, inaccessibility, and finances must be considered. Disregarding these obviously hopeless eyes, only 39 unsuccessful results were reported, i.e., 13.7 per cent of the total.

III. *What are the reasons for failures? What are some of the problems of glaucoma?*

The principal reason for failure in all except six cases in this three-year period is delayed treatment. It seems evident that if treatment is begun early in the course of the disease, a favorable prognosis for vision may be offered. A survey of the correlation between the duration of symptoms before diagnosis and the beginning of treatment is as follows:

Duration of symptoms	Per cent of good results
0- 3 months	85 per cent
4- 6 months	74 per cent
6- 9 months	65 per cent
9-12 months	35 per cent
12-25 months	33 per cent

These percentages emphasize strikingly the delay before treatment was begun is the largest single factor. The average duration of ocular symptoms before treatment was begun was 2.6 years (31 months). Ninety of the 96 recorded enucleations were necessary because of absolute glaucoma or rapidly progressive glaucoma and in every one of the 90 cases, delay was a factor.

Fear of surgery is a factor mentioned by many patients as the reason for the delay before seeking aid.

Poor cooperation by the patient after therapy was begun is the second ranking factor in the analysis of failures. Nine per cent of the total failures reported were believed ascribable to poor follow-up care, irregular or spasmodic therapy, or refusal of treatment by the patients.

All physicians speak of the "hypertensive type" of patient, and of the "peptic ulcer personality." There are no statistics to prove that there is a "glaucoma type" of patient, but it is a clinical observation that the tense, emotionally unstable individual seems more prone to develop glaucoma. This further complicates the treatment of glaucoma because it is difficult to obtain the necessary complete and prolonged cooperation from this type of patient.

Sixteen cases of secondary glaucoma caused by intumescent lenses

were discovered during the past three years. As the cataractous changes occur in the lens, the lens often becomes swollen, thus mechanically interfering with the drainage of the eyeball. These cases often are overlooked by the physician caring for patients with immature cataracts of whatever type. Moreover, 15 cases of secondary glaucoma occurring during or as a sequel to iritis were noted. Two cases of glaucoma secondary to retinal vein thromboses were recorded, as were 17 caused by intraocular hemorrhages. These cases of secondary glaucoma were handled with success in most cases. They are not necessarily classified as failures but are mentioned as problems in glaucoma, contributing to potentially unfortunate end results.

54 per cent of the glaucoma patients observed at the University Hospitals had bilateral glaucoma. The second eye in most cases exhibited signs of glaucoma some months or years after the involvement of the first.

An explanation for one difficulty in diagnosis becomes evident in analyzing these case records. Only a small percentage of patients showed the classified symptoms of glaucoma, that is, a red, painful eye. Only 11 per cent gave a history of ocular pain, 10 per cent complained of vague discomfort, 5 per cent of seeing haloes around lights, and 7 per cent of inflamed appearing eyes. The majority of patients had no other sign or symptom except gradually decreasing vision. Undoubtedly, one obstacle to securing these patients in the stage when best results may be attained lies in the difficulty of making a diagnosis of chronic compensated glaucoma, that is, non-inflammatory glaucoma. The physician or optometrist is prone to think of the classified picture of glaucoma and to think of glaucoma as a condition to be differentiated from iritis. Actually, most glaucoma begins insidiously without redness, pain or haloes.

IV. *How can blindness from glaucoma be prevented?*

The greatest handicap in therapy of glaucoma is the delay before diagnosis is made. The problem of prevention of blindness resolves itself into the problems of early diagnosis and early treatment before serious visual impairment has occurred.

While infantile and juvenile forms of glaucoma are much rarer than the adult type, it seems evident that in a certain number of children useful vision could be retained if every case suggestive of buphthalmus or megalocornea were referred promptly for treatment.

One cannot but be impressed with the importance of the inclusion of ocular examination in all physical examinations. Recording of the

visual acuity is helpful, but is not a complete eye examination. The intraocular tension should be checked at least annually, and the fundus inspected for evidence of nerve head changes indicative of increased intraocular tension. Periodic health examinations would be helpful in this respect if ocular examinations were included. Periodic ocular examinations certainly are as valuable to the patient as routine dental inspections.

The diagnosis of glaucoma, especially of chronic glaucoma, presents difficulties which may be overcome if the examiner would *think* of glaucoma in every case with ocular symptoms. Moreover, if patients with maturing cataracts were checked periodically as to their intraocular tension, the incidence of secondary glaucoma from this cause would be lessened.

BOOK NOTICES AND REVIEWS

Books received are acknowledged by notices in this department. Special selections will be made for more extensive review in the interest of our readers as space permits.

INDUSTRIAL OPHTHALMOLOGY.[1] Hedwig S. Kuhn, M.D. Published by the C. V. Mosby Company, 3523 Pine Blvd., St. Louis, Mo. 265 illustrations, 294 pages, cloth, $6.50, 1944.

The field of industrial vision has been covered only by monographs up to the present. It is fortunate that the first complete treatise on the subject has been written by Dr. Hedwig S. Kuhn out of her years of experience in the many phases of vision in industry and her interest and leadership in research in industrial vision. To a firm foundation of knowledge in the science related to vision and clinical application of it, she has added a rich experience in the practice of industrial ophthalmology.

"Industrial Ophthalmology" is a revelation to any clinician who has little or no experience in industrial practice. The section on "Job Analysis" is worth the price of the book for any optometrist. One is made to wonder how he has ever successfully supplied clinical corrections to the modern skilled worker on the basis of the sketchy information supplied by the patient. As the author states, "(The) refractionist has now a new job. It is to attempt to relieve the strain and to improve, as far as possible, each individual's abilities to operate his particular machine."

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[1]An earlier review will be found in the June, 1944, issue. Vol. 21, No. 6, pp. 247-248. The author of this review is a Vice-President of the Indiana Association of Optometrists.

"Tests and Techniques" cover modern methods and equipment that are adaptable to the efficient and rapid testing of eyes in industry. The author states that standard basic visual data is required as follows: (1) Visual acuity for distance and near without correction. (Unaided acuity.) (2) Visual acuity for distance and near with correction. (Working acuity.) (3) Stereopsis for distance with correction. (4) Muscle balance for distance and near, with and without correction. (5) Color appreciation.

Like the Industrial Vision Committee of the A. O. A., the author believes that visual tests, for the purpose of proper placement of employees, should be made under the supervision of the professions but not, necessarily, by an ophthalmologist or optometrist. She suggests that it be done by a trained technician, which she defines as a "recorder of facts." "He must never interpret, never become subjective, never feel impelled to alter or change a given routine because he thinks his experience justifies it."

The author's discussion of visual rehabilitation is a section that should be studied carefully. "It is up to each one of us to solve the immediate problems, even if we do have to discard the old way of doing things and learn new methods with good grace and speed."

The author does not attempt any dogmatic statement on the necessity of universal, compulsory wearing of goggles, but she does state, "The consensus of opinion among safety men is, I believe, that an all-out compulsory goggle plan is the best wherever possible."

The chapter on eye protection is indispensable to any professional man expecting to approach management and sell them on a protective-corrective goggle program. Facts and figures are given to answer management's questions. A typical professional-industrial agreement is also given to guide the drawing-up of such contracts.

Dr. Kuhn stresses the servicing of the goggles—whether plano or prescription. She suggests that every plant of 2,500 or more employees should have the services of a "full time, specially trained man, whose sole duty it is to take care of dispensing, adjusting, readjusting and repairing industrial goggles. It is not a sound policy to wait until complaints come in." "If all industrial eyewear, whether protective or otherwise, is handled as an ophthalmic problem, it will be possible to take greater advantage of both applied optical science and the professional services."

A review, necessarily, cannot mention all of the interesting and

instructive treatment of the relatively new and untried field of assistance to industrial vision. The ophthalmic professions are still in the pre-industrial stage and this book can well be the door that opens to wide vistas of increased service to practitioners. It stands as a monument to the splendid pioneering in and intensive study of industrial vision by Dr. Hedwig Kuhn.

We do not want to leave the impression that, like the usual reviewer, we only recommend this book to an optometrist. He must digest it carefully to render the kind of service that is expected of him in his clinical practice. If he intends to devote his talents more specifically to caring for industrial vision, a careful study of this book is an essential prerequisite. G. F. KINTNER.

PROCEDURE AND INSTRUMENTATION

Rudolph H. Ehrenberg

A department wherein discussions will be carried on relative to the value of various experimental and clinical techniques as employed by practicing optometrists, and also in which the instruments used by optometrists in various phases of their work, will be subjected to some critical evaluation.

NEAR POINT CARDS

An interesting review of near point cards appears in the pamphlet recently prepared by Stoll in the Bureau of Visual Science of the American Optical Company.

Near point cards were first provided nearly a century ago, according to Stoll. The design through a large part of that time did not show much change. In the earlier cards, few advances were made except for changes in subject matter. The near acuity in presbyopic conditions was the only interest.

More recently that has failed to satisfy. As the understanding of near point efficiency has increased, targets began to show revision. First for comparative understanding of far and near acuity. Second, that compensation could be accurately and equitably awarded. Still more recently, to include the increased number of tests for near point efficiency.

Much has been learned about the relative legibilities of different types. Then there are the effects of glare and also that emotional factors affecting the reader must be considered when designing cards. Foreign language cards and tests of acuity for illiterates at near are supplementary.

Present sources of near point cards are many. The American Medi-

cal Association provides a card similar to the Snellen chart for distance. Jewell has cards that incorporate the ideas of many optometrists. Most supply houses have the various types available.

Stoll has prepared a worthwhile service in this monologue. One that should be a welcome addition to all personal professional libraries. The American Optical Company has printed them. Copies may be obtained from that company at Southbridge, Mass. at no cost.

MORE INDUSTRIAL LENSES

The news of methods that will greatly increase the number of industrial safety lenses is welcome to the optometric and ophthalmological professions. For despite plant regulations, all too many men in industry are deprived of this fundamental protection.

The device according to the American Optical Company engineers is a heating and chilling unit of rotary type. Rotating arms carry the lenses through the furnace past compressed air jets. It is the shape of these jets that provides the desired distribution of air over the heated lens, thus providing an important part of the hardening or toughening operation.

DRIVER TESTING DEVICES

The American Automobile Association has since 1936 engaged in testing and providing the equipment for testing automobile drivers. Some 35,000 persons have been tested by their own people and by lay persons.

The purposes advanced for such screening are sound, and as advertised by lay groups, contribute to our improved understanding of the skills and reactions in handling an automobile.

The tests of an optometric nature are properly simple and include color vision, eye dominance, field of vision, glare acuity, and distance judgment.

Other tests include brake reaction, jerk recorder, reaction time and traffic quizzer.

As an inducement to secure co-operation of school and civic groups, the equipment can be borrowed for short periods of time. Also available are drawings and any or all the equipment can be purchased from the Association.

In the opinion of the writer such screening can be handled by lay groups. However, without the co-operation of the professions the specific

end of greater highway safety will not be met. Those shown to be "accident prone" or those failing the tests will need thoughtful care and guidance. That care to the individual and counsel to the American Automobile Association are the profession's responsibility.

ABSTRACTS

A department in which will appear abstracts of the literature of optometry, ophthalmology and applied optics. These will be classified according to the following list although contributions to all sections will not necessarily appear in each issue.

1. Ocular Refraction.
2. Physiological Optics and Color Vision.
3. Ocular Muscles.
4. Orthoptics and Reading.
5. Anatomy, Histology and Embryology.
6. Ocular and General Pathology.
7. Ophthalmic Lenses and Material.
8. Instruments.
9. Hygiene and Illumination.
10. Applied and Physical Optics.
11. Education, Sociology and Economics.
12. Miscellaneous.

9. HYGIENE AND ILLUMINATION

SIGHT SAVING CLASSES IN LOS ANGELES. W. M. Gardner. Western Optical World. 1943, 31, 12, 472.

The author is Supervisor of the Eye and Ear Unit of the Health Service section of the Los Angeles City School System. He claims that in Los Angeles, any pupil who by virtue of any abnormal condition of his eyes finds it unduly difficult or impossible to keep up with the regular class or who by the regular class work is aggravating an already existing, abnormal ocular condition, is entitled to attend a sight saving class.

In these special classes a pupil may move his desk to any desired position in the room either in regard to copy matter or illumination. Sight saving class teachers have had special training for their particular work and are usually teachers possessing great patience and exceptional ability. Sight saving classes are not coddling classes. Pupils permitted to attend these classes are expected to keep up with their work just the same as the pupils in regular classes. For this reason a sight saving class teacher is not asked to try to teach a child with lower than low normal intelligence, nor does her teaching load ordinarily exceed 15 pupils. We can readily see why, says Gardner, when we understand that in one such class in an elementary school there may be pupils from 4 or 5 different grades, each grade studying different assignments. Thus the teacher has all she can do assisting visually handicapped children in so many different subjects and would not have time in addition for individual instruction to the mentally handicapped.

Gardner points out that because these children must have average intelligence it is wrong for one to speak of any odium or stigma being attached to a child so placed. Nor should one consider that the child has been, in any sense, demoted. A visually handicapped child does not develop an inferiority complex by association with other visually handicapped children. In fact an inferiority complex is far more likely to develop in such a child if he is forced to continue in a regular class of children with good eyes, behind whom he will gradually fall because of his visual handicap. The unfairness of such a situation may discourage him and make him resentful, truant and delinquent. A psychic upset of a child because of assignment to a sight saving class is usually due to the attitude and influence of an uncooperative parent.

Sight saving class rooms in Los Angeles schools are practically "Home Rooms" for study under the more ideal conditions of good illumination, adjustable seats and desks and larger print and where, also, the child receives far more individual help, even being read to if necessary.

Recitations, however, are heard in a regular classroom with the normal visioned pupils, thus is maintained contact and educational competition. It is an *opportunity* for a visually handicapped child to be in a sight saving class for it compensates for his handicap thus allowing him eyual chance to compete mentally. Therefore a child so placed may, in spite of his physical handicap, excel the normal visioned pupils of his own class in scholarship.

The length of the periods of study in which the children use their eyes for close work is in accord with the recommendations of their own private or clinic eye specialist. There is no necessity for a school child to be kept out of school just because of impaired vision. Gordon claims they have a place for him in which he will not injure his sight. If he is so bad that he should do no close work he should be placed in a Braille class so that he may not be detained in his education but obtain it through his finger tips thus saving his sight for future enjoyment.

It is desired that, before a child is assigned to a sight saving class, he shall have been refracted and glasses secured if needed. No eye specialist need feel it is an adverse criticism of his ability if his patient is assigned to such a class. The visual acuity of the members of these classes is rechecked by the use of the "Broken Square Eye Chart" and their glasses adjusted each semester. If any adverse change is noted they are urged to return to their eye specialist immediately. An eye specialist should gladly

advise his young patient who is visually handicapped to attend such a class so that he may keep up with the pupils and playmates of his age and yet not injure his eyes nor further aggravate his ocular condition in obtaining his education but preserve his sight for his future occupation and pleasure. A. V. F.

VICTORY IN SIGHT. A. A. Brainerd. Better Light Better Sight News 1943, 11, 9, 8.

The author outlines how industrial lighting systems depreciate from 2 to 6 per cent each month due to depreciation in lamps, overloaded circuits, and accumulation of dirt on the lamps and fixtures. He points out in this connection that one good man-hour of housekeeping in the plant may save hundreds of man-hours of productive work.

T. O. B.

FLUORESCENT LIGHTING MOVES ON. Special Report. Fortune. 1943. 27, 6, 76.

"Fluorescent lamps operate on the principle discovered in 1602 by a Bolognese cobbler and formalized in 1852 by Sir George Gabriel Stokes: when ultraviolet radiation falls on certain materials, it is converted into radiation of a longer wave length, which is light.

"The tube contains a small quantity of the inert gas, argon, and a tiny speck of mercury, which vaporizes when an electric current passes through. The electric discharge acts on the mercury vapor and argon to generate large amounts of ultraviolet radiation. When this falls on the tube coating, it creates fluorescent light. Different coating substances give different color tones. Calcium tungstate, for example, produces a preponderance of blue light; magnesium tungstate, blue-white; zinc silicate, green; cadmium borate, pink; and zinc beryllium silicate, yellow-white. Mixing the fluorescent powders (commonly, but incorrectly, called "phosphors") gives almost any desired shade.

"Out of a given quantity of electric energy, fluorescent tubes produce 18.5 per cent light, while the best incandescent lamp produces about 9 per cent, the ordinary run 3. Remainder of the current is dissipated in heat—unpleasant in the home and harmful to workers in a factory where a high intensity of light is required." A. V. F.

VISION IN DEFENSE INDUSTRY. E. H. Ridgeway. Iowa Optometrist. 1943, 21, 2, 5.

In making visual surveys in war plants, Ridgeway suggests (1) that whatever visual tests are to be used must be taken to the man at his place of work in the plant. The worker should not be taken from his place of work and the tests should be made under his normal working conditions. (2) The visual tests should be brief and should not interrupt his work for more than 90 seconds. (3) The tests should determine the worker's visual acuity at the working distance both monocularly and binocularly. They also should determine whether or not the worker uses both eyes on his task. (4) The tests should determine whether or not increased illumination would be of benefit to the worker. C. C. K.

NORMAL EYES. B. C. Hersch. Optometric Weekly. 1943, 34, 4, 97-99.

Hersch feels it is regrettable that the words "normal" and "defective" have been applied with such conclusiveness to the eyes. The ocular state of emmetropia is not seen with great frequency. Studies of statistics on the incidence of eye "defects" seem to indicate that the majority of people accept plus, require minus to see clearly at far or have ellipsoid corneas. This would indicate that statistically ametropia is normal and emmetropia abnormal. This agrees with modern physiological thinking wherein ametropia is considered as a normal reaction of the organism to its environmental needs. A non-statistical but practical definition of normal is that it is the expected or approved. Ametropia is a normal reaction but taking the last mentioned definition, it is not a normal state.

Hersch also claims that it is obvious that improper terminology has impeded accurate thinking. As new material is made available from the research laboratories that material as well as accompanying terminological changes must be accepted and made a part of the working tools of the profession. When modern research disproves established and accepted principles and terms they should be abandoned even before they have been replaced by equally facile ones which modern research substantiates and offers as alternates. C. C. K.

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11. EDUCATION, SOCIOLOGY AND ECONOMICS

OPPORTUNITIES FOR THE VISUALLY HANDICAPPED THROUGH JOB ANALYSIS. E. Lester. Sight Saving Review. 1943, 13, 1, 29-35.

It is a common belief that modern industrial production depends on good vision but the problem is: "What is meant by good vision?" Many of the larger industrial concerns have made the Snellen visual acuity notation of 20/20 or 20/30 a prerequisite to pass the pre-employment vision examination and an individual failing to pass this eye test may be rejected from employment because of defective vision. If we are going to evaluate the prospective employee's visual ability to perform a certain job, other visual functions in addition to acuity must be tested, because visual acuity for distance alone is not an adequate index of visual efficiency.

It is important that binocular vision be evaluated, since the individual uses this type of vision in many occupations. Another factor that is of vital importance in the performance of certain tasks is stereopsis. A one-eyed man lacks this ability and, in certain occupations, this might constitute a serious hazard to his fellow workmen. Another function that is of importance is muscle balance, or lack of it. Many young men who otherwise have been able to meet the high physical standards required of aviators have been eliminated because of this type of eye defect. Another factor that should be considered before individuals are placed in jobs involving a high degree of color discrimination—as, for example, trainmen who must observe colored signals—is whether or not they are color-blind. In certain occupations peripheral vision or the ability to perceive objects in the area surrounding the direct line of vision is necessary and should be measured.

All occupations do not require the same degree of visual function, and the important thing is to place the workman in a job which takes into consideration his visual ability. The value of the job analysis cannot be questioned. However, too few industries have done adequate analyses of the operations carried out within their plants and, as a result, do not know the visual requirements for certain jobs. Before placement of a visually handicapped individual can be considered, one must know not only how much, but what type of vision the individual possesses, and how he or she can best use this vision with the minimum possibility of further loss. This is the responsibility of the social worker who is trying

to help the visually handicapped person find suitable employment.

L. P.

TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

by J. Fred Andreae, Secretary

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

SPEAKERS AT ANNUAL MEETING OF ACADEMY

The list of those who will present papers at the American Academy Convention in Chicago, December 10, 11 and 12, is impressive and will insure an interesting and informative program. One or two papers may be added at a later date, but those of which we are certain will give us a well rounded group of speakers.

Among those who will present papers are Doctors Glenn A. Fry and Henry Hofstetter of Ohio State University; Doctors R. M. Hall, Matthew Luckiesh and R. S. Jordan of Cleveland, Ohio; Doctors Robert A. Bannon and Rita Walsh of the Dartmouth Eye Clinic; Doctor Lawrence P. Folsom of South Royalton, Vt.; Doctor Richard Feinberg of New York City; Doctor Carel C. Koch of Minneapolis, Minn.; Doctor J. A. Seifert of Detroit, Mich.; and Doctor Matt Alpern of the U. S. Army.

CORRECTION

The book "Principles and Practice of Ophthalmic Surgery" by Spaeth, was reviewed in the August issue of the American Journal of Optometry.

In error this work was credited as being published by the C. V. Mosby Company of St. Louis. The publishers of Spaeth's new work are Lea & Febiger, Publishers, 600 Washington Square, Philadelphia, Pa.

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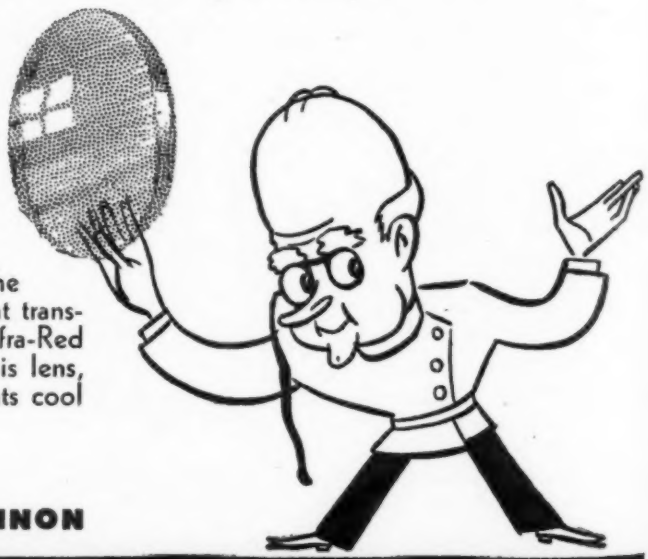

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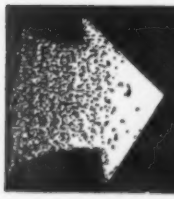

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V. When authors receive proofs for revision, they should correct and return these without delay. We beg, however, to remind our contributors that changes in the manuscript necessitates resetting, this causing much additional expense, so we ask that alterations be limited to what is of essential importance.

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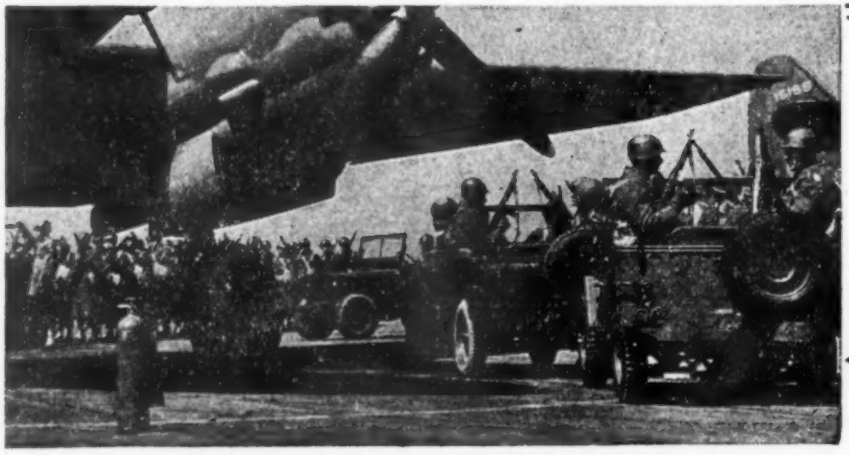

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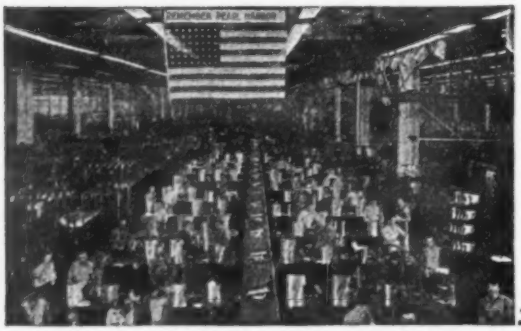

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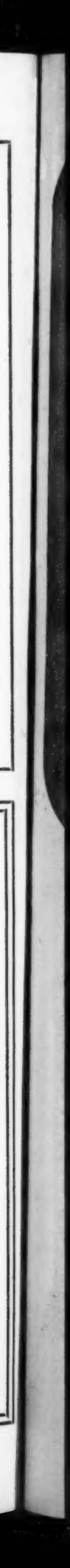

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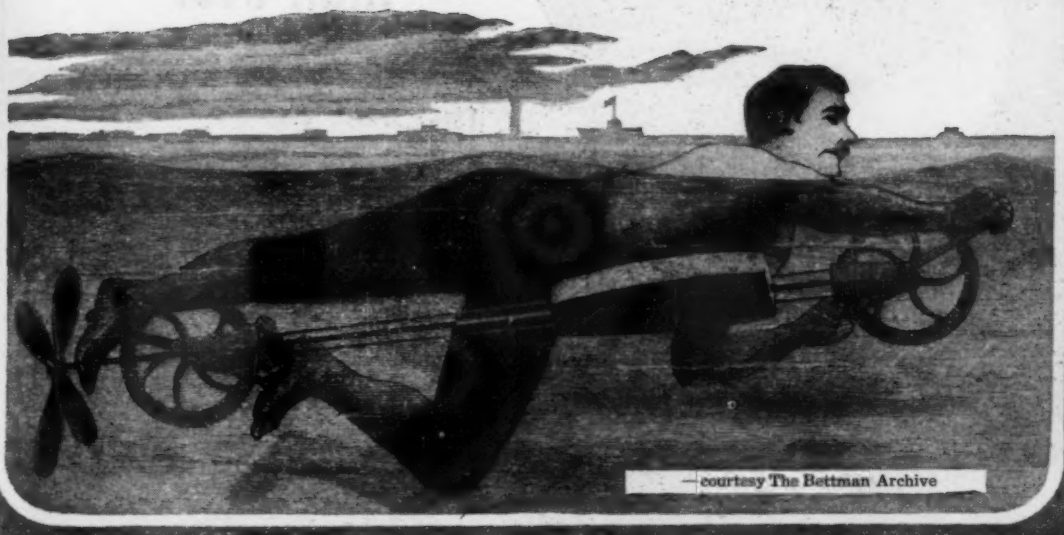

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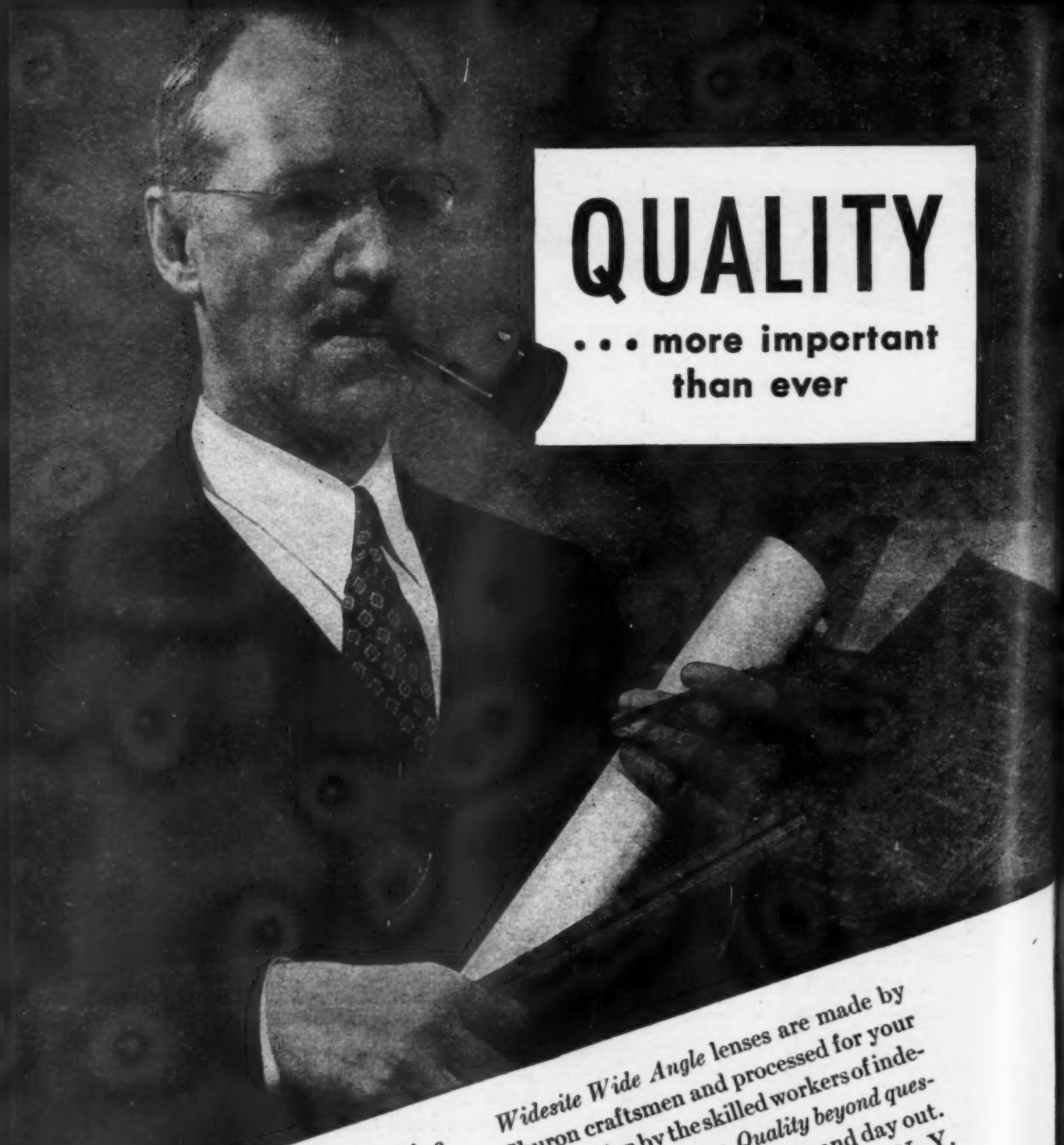

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